INSTITUTE OF PAPER CHEMISTRY
Appleton · Wisconsin

GENETIC IMPROVEMENT OF LARCH

Project 3409

Report Four
A Progress Report
to
MEMBERS OF GROUP PROJECT 3409

March 1, 1984

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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Mosinee Paper Corporation

Scott Paper Company

The Mead Corporation

Thilmany Pulp & Paper Company

Potlatch Corporation

Consolidated Papers, Inc.

Wisconsin Department of Natural Resources

Michigan Department of Natural Resources

Georgia-Pacific Corporation

Michigan Technological University

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THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

GENETIC IMPROVEMENT OF LARCH

SUMMARY

This past year has been a routine but busy year, and 1984 and 1985 promise to be both interesting and exciting because of the grafting work underway and the site preparation work that will be required both for the first seed orchard and for the 1985 conversion plantings. During this past year a total of 3 European larch (Larix decidua), 7 Japanese larch (L. leptolepis), and 4 Dahurian larch (L. gmelini var. gmelini) were selected, measured, and added to our list of parent trees. This brings the total number of parent trees available for use in seed orchards to 132. Grafting success, although lower than 1982 because of available scion size, was a very acceptable 82%. Well over 100 of the 132 trees have now either been planted or are ready for planting in our scion arboretum.

Selection index calculations have continued as complete data becomes available on selected trees. At present, selection index values have been determined for 26 European and 23 Japanese larch. The tree-to-tree variation in selection index values appears to be greater than we first anticipated. This variation will, however, make it easy for us to identify marginal trees.

Seed availability, seed costs, and anticipated seed orchard seed production were several aspects of the program that received considerable attention this past year. Cone collections from heavily flowering European larch in southwestern Wisconsin indicate that our earlier estimates of seed production were conservative. Production rates could run as high as 50 kg per acre during good flowering years. Limited amounts of good quality seed have been located at costs as high as $600/kg, depending on source.

Four replicated larch trials have been established on company lands. These plantings, which include 3 container and 1 bare root planting, have not been without the usual establishment problems, including vegetative competition, drought, frost, and even gophers. There appears to be a need to establish one or two additional trials in order to properly compare several new potentially valuable seed sources. Also included in the report are descriptions of six larch demonstration plantings which we feel will provide valuable survival and growth information in the near future.

Wood quality continues to be an important parent tree selection criterion, and the base line data we use for evaluating parent trees for fiber length, specific gravity, and extractives levels were updated this past year. Also, a review was completed that investigated the potential of larch as a raw material for solid wood products. This review suggests larch can, or has been, used for poles, laminated lumber, furniture, plywood, composite board, gypsum and cement board, and molded wood products.

Plans for the coming year include the establishment of a bare root replicated trial with the Wisconsin DNR, grafting of 20 clones for the first seed orchard, herbicide trials with larch, and a small larch mycorrhizae planting. Also included in our plans are the field, nursery, and site preparation work required for the 1985 conversion plantings which will compare site preparation methods and bare root *vs.* container stock at 3 locations.

INTRODUCTION

Each year, as more and more evidence accumulates on our future wood and fiber needs, concern increases with regard to the available supply of conifer fiber during the 1990's. Extensive planting programs using genetically improved trees have been widely advocated as one approach to solving the fiber raw material problem. The economics of reforestation hinge upon the use of species that are easy to regenerate, capable of rapid growth, and able to produce wood that can be used for both short rotation fiber production and in longer rotations for solid wood products. There is increasing evidence that to produce the types of trees needed in a reasonable period of time will require the use of the clonal forestry approach.

Use of the conventional seed orchard approach fails to capture all of the potential genetic gains available to forest managers. Use of clonally propagated trees in operational plantings will result in maximum genetic gains. Immediate additional genetic gains of up to 30% can be obtained in growth rate, wood quality, and other properties by using outstanding clones instead of seedlings from seed orchards. Clonal propagation methods include grafting, rooting, and the use of tissue culture techniques. Needed are outstanding selections and an inexpensive clonal propagation method. Use of tissue culture methods is believed by many to be the eventual solution to the clonal propagation problem.

How is the clonal forestry approach expected to impact the Institute's cooperative larch tree improvement program? A properly organized seed orchard tree improvement program will be the source of the first trees for clonal propagation and the source of needed natural variation. Early clonal plantings are expected to be a mixture of clones which will be used on special sites to supplement conventional seed orchard plantings. The use of a mixture of clones allows the forest manager to build into his planting as much genetic variation as he desires. Presently, there is a need for conventional tree improvement programs. The genetic material produced in these programs will be used as the starting point for additional genetic gains through clonal forestry.

SELECTION AND PROPAGATION

NEW SELECTED TREES

Parent tree selection and propagation were again an important part of the larch program in 1983. The total number of trees selected in 1983 was less than in previous years, due in part to our having visited and selected trees from many of the larger plantings in Wisconsin and nearby states in 1980, 1981, and 1982. Selections were made this past fall in the states of Michigan, Wisconsin, and New Hampshire. They included three European larch (Larix decidua), seven Japanese larch (L. leptolepis), and four Dahurian larch (Larix gmelini var. gmelini). Dahurian larch grows extensively at low elevations in Eastern Siberia, Northern Manchuria, and North Korea and appears to be a species with good form and rapid growth that, when used as a parent tree, could be expected to increase the frost resistance of certain types of larch hybrids. Figures 1 and 2 illustrate the size and form of four of the trees selected in the fall of 1983.

The addition of the above 14 selected trees brings the number of parent trees available for use in establishing seed orchards to 132. We expect to select and add only a total of three or four more United States grown Japanese and three or four U.S. grown European larch to the program. There will, however, be a number of additional selections added through an exchange of selections with cooperators in Canada, Europe, and South Korea. Many of the foreign selections have been progeny tested and will make valuable additions to the program. Presently, we anticipate the number of selected trees (Japanese, European, and Dahurian) will eventually reach 160 to 170. The selection of Eastern larch or tamarack (Larix laricina) is expected to begin in 1985 if members of the cooperative program give their approval.

Figure 1. The tree on the left, LL-1-83, is a 23-year-old Japanese larch selection from an International Provenance Trial growing near Rhinelander, Wisconsin on a sandy site. The tree on the right is a European larch selection from a 24-year-old planting in Upper Michigan. Both individuals have excellent form and have done well under the varying site and growing conditions.

As mentioned in earlier reports, the selection criteria used are similar to those used for other tree species and by other tree improvement groups. We, in our program, are attempting to maximize genetic diversity by obtaining good quality trees from as many appropriate geographic origins as possible. During the selection process we try to avoid overselecting sources from any one geographic area. Geographic origin information is not always available, but it is hoped that our work with isozymes will help determine the origins of the various unknown selections. During the selection process, prospective parent trees are evaluated for stem form, branching habit, growth rate, and crown characteristics. We also take topographic position information and, in a number of situations, evaluate the soils. Ten-millimeter increment cores are taken to provide wood for extractives, specific gravity, fiber length, and age determinations. Information on frost hardiness, insect and disease problems, flowering, and time of bud break are also expected to be available eventually for the selections. Table I gives a brief summary of the characteristics of the newly selected parent trees. Appendix Tables XIV, XV, and XVI, summarize the information available on the geographic origin of all larch selections.

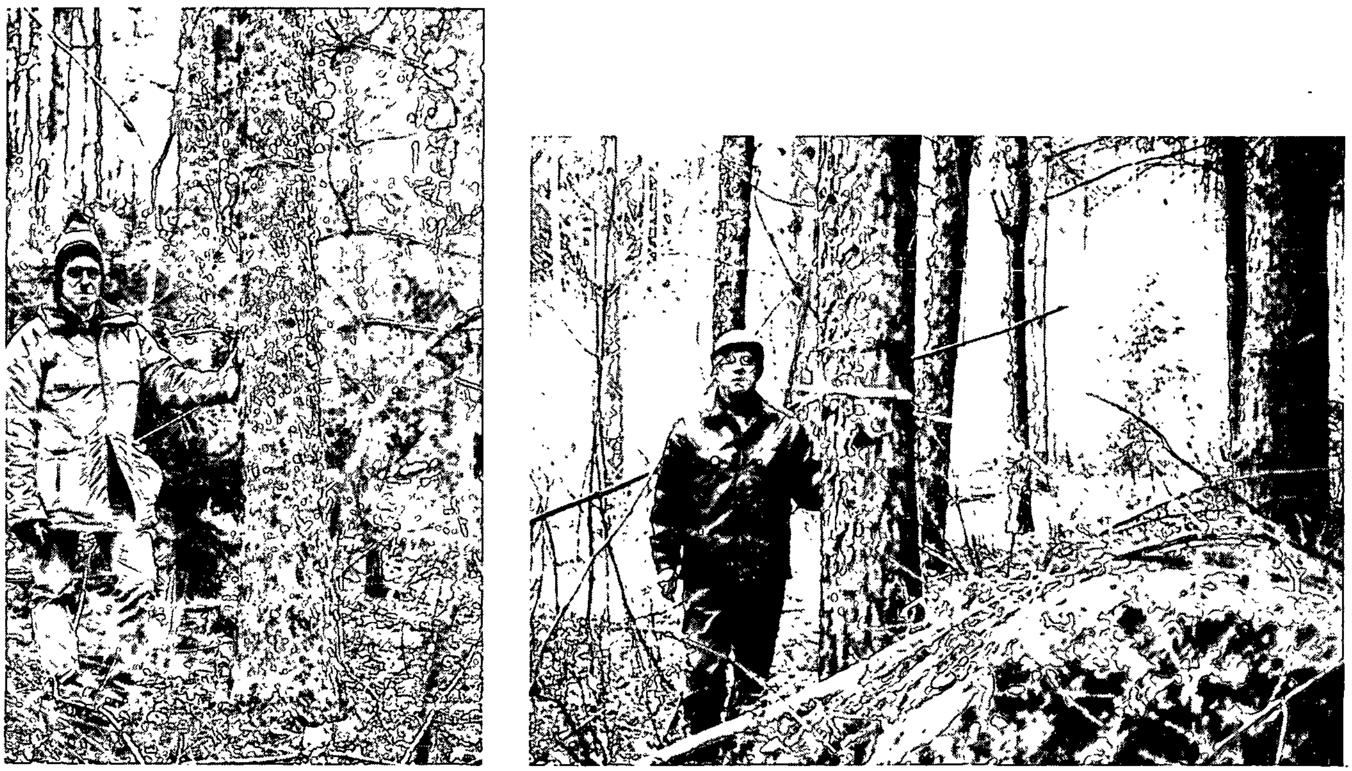

Figure 2. The above two trees are part of a provenance test on the Fox State Forest in New Hampshire. The Japanese larch parent tree selection on the left (LL-7-83) was located with the assistance of David Maass (Scott Paper Co.) shown above. The tree has excellent form, is 73 feet tall, 11.0 inches in diameter, and 26 years old. The Italian source of European larch on the right (LD-2-83) also has excellent form, is 82 feet tall, 13.1 inches in diameter, and 48 years old.

TABLE I

SELECTED TREES MEASURED AND EVALUATED IN 1983

Tree Number[a]	Age, yr	Total Height, ft	Diameter B.H., inches	Straightness[b]	Branch Weight[c]	Specific Gravity[d]	Geographic Origin
LD-1-83	24	68	8.7	3.5	3	0.42	Unknown
LD-2-83	48	82	13.1	5	2	0.49	Italy
LD-3-83	46	86	10.7	4	2	0.51	Scotland
LL-1-83	23	45	7.3	3.5	3	0.43	Yatsuga Mts.
LL-2-83	23	46	7.2	4	2	0.45	Yatsuga Mts.
LL-3-83	23	43	6.4	3	2.5	0.39	Yatsuga Mts.
LL-4-83	24	52	7.4	3	3	0.45	Unknown
LL-5-83	24	46	7.9	3.5	3	0.42	Unknown
LL-6-83	26	69	9.9	4	2	0.40	Unknown
LL-7-83	26	73	11.0	4	2	0.48	Central Honshu
LDa-1-83	23	47.5	9.1	4	3	--	Kuriyama, Hokkaido Japan
LDa-2-83	23	49.5	8.8	4	3	--	Kuriyama, Hokkaido Japan
LDa-3-83	46	77	11.1	4	4	0.48	Unknown
LDa-4-83	23	49	8.1	4	4	--	Kuriyama, Hokkaido Japan

[a]LD = *Larix decidua*, LL = *L. leptolepis*, and LDa - Dahurian larch (*L. gmelini*).
[b]Stem straightness ranked from 1 to 5, poor to good.
[c]Branch weight ranked from 1 to 5, good to poor.
[d]Oven dry weight ÷ green volume - measurements made on b.h. 10 mm increment cores, rings 14-16. Fiber length to be completed by 5/1/84.

1983 GRAFTING

With the exception of two selected trees in Michigan and ten selected trees in Pennsylvania, all of the parent tree selections made through 1982 have been grafted. Of the 130 selections made to date, 70 have been established in the Greenville arboretum, with an additional 36 clones to be planted this spring. Figure 3 provides an illustration of the growth of the grafted clones after 3 years in the arboretum.

A total of 793 grafts were made this past year involving 31 _L. decidua_ clones, 28 _L. leptolepis_ clones, 2 _L. gmelini_ var. _gmelini_ clones and 1 _L. gmelini_ clone. The overall average grafting success was 82%. This average was lower than the 96% survival of grafts in 1982. The lowered success was caused by several factors but primarily by scion size and condition. Scions available from a number of parent trees were quite small and limited in number. As a consequence, a number of grafts were made using a crown veneer and modified cleft graft, both of which produced acceptable grafts but with lowered survival. Scion material that was shipped in by cooperators also tended to result in grafts with lowered survival as opposed to field collections where the scion material was brought in and grafted the same day or within the same week.

When the clones now being planted in the Greenville arboretum are established, they will serve as a ready source of fresh scion material of a size suitable for grafting. As can be noted in Fig. 3, the arboretum is developing well. Clean cultivation, fertilization, and protection from animals have produced a well-established arboretum. The same level of care will be needed when seed orchards are established.

Figure 3. The Japanese larch graft shown on the left has been in the Greenville larch arboretum for 3 years. The photo on the right further illustrates the appearance and growth of both European and Japanese larch after 3 years. Intensive culture has assured excellent growth and survival of often a limited number of grafts from a parent tree selection. The arboretum is rapidly developing into a ready source of scion material and within a few years will be providing information on flowering.

The changes in grafting procedures and graft care discussed in last year's report were employed again in 1983 with no additional changes. The large number of grafts that will need to be made for seed orchards has made necessary the construction of a shade area and grafting area at the Greenville Nursery. This will reduce the amount of understock and graft handling as well as giving ready access to scions from the arboretum as they are needed.

SELECTION INDEX CALCULATIONS

There are a number of ways a tree can be improved for more than one character at a time. A single trait can be improved followed by continued selection among the resulting individuals to improve the second trait and so on, or an attempt can be made to improve a number of characters at the same time. This latter approach is more efficient than the first if the characters are weighted properly with respect to each other. Each character needs to be weighted according to its economic importance, its heritability, and its correlation with other characters.

The traits incorporated in the larch selection index are volume growth, growth advantage[1], stem straightness, branch weight, form factor, crown area, specific gravity, fiber length, and extractives level. Because the larch project is an applied program, the heritability of the various traits incorporated in the selection index has not been determined. Literature statements and experience in previous programs leads to the assumption that most of these characters are under at least a moderate degree of genetic control. Each character has been weighted to have an impact on the final selection number according to its preceived relative importance and desirable or undesirable influence on growth and wood quality.

The present selection index has been used with 26 European larch and 23 Japanese larch selections. The mean value for European larch is 33.6, and it is 26.6 for Japanese larch. The difference between the selection index values for the two species is due to a greater average volume growth and a greater average growth advantage for the European larch.

[1]Advantage of selected tree over nearby check trees.

European larch is widely distributed and has distinct morphological and growth differences between the various regions. It is this diversity and accompanying natural variation that makes European larch such an attractive candidate for improvement. Japanese larch, however, in its natural range, is limited to central Honshu, the principal Japanese island. Provenance tests have shown that there are few differences between provenances of Japanese larch for a number of traits with the exception of growth rate. Apparently, it is the greater variation exhibited by European larch and the uniformity of the Japanese larch that is being reflected by the difference in average selection indexes.

The value of the selection index, however, is not in comparing species but in comparing selections within a species. Tables II and III list the selections for which selection indexes have been calculated. The selection index values range from 18.3 to 62.4 for European larch and from 14.0 to 42.7 for Japanese larch. The major factor contributing to the wide variation in the selection indexes is the growth advantage value. The index identifies those trees that have outgrown neighboring dominant and codominant stems and possess average to better than average values for other traits. The index also identifies marginal selections, which will be more closely evaluated before the decision to remove them from the program is made.

The selection index has been modified a number of times and now provides a good basis for comparing clones. Additional information, such as provenance, disease resistance, seed and pollen production, and flowering synchrony will also need to be considered in the final evaluation of each clone.

TABLE II

SELECTION INDEXES

European Larch

Clone	Selection Index	Clone	Selection Index
LD-10-79	30.3	LD-11-80	28.6
LD-11-79	31.1	LD-24-80	29.5
LD-12-79	34.6	LD-26-80	37.4
LD-1-80	39.1	LD-27-80	34.2
LD-2-80	18.3	LD-7-81	29.4
LD-3-80	20.3	LD-11-81	35.1
LD-4-80	29.5	LD-12-81	52.0
LD-5-80	38.2	LD-13-81	62.4
LD-6-80	38.2	LD-20-82	34.5
LD-7-80	37.7	LD-22-82	38.4
LD-8-80	35.8	LD-23-82	29.3
LD-9-80	34.0	LD-24-82	25.0
LD-10-80	28.0	LD-26-82	33.4

TABLE III

SELECTION INDEXES

Japanese Larch

Clone	Selection Index	Clone	Selection Index
XLL-2-59,S-1	25.6	LL-12-81	38.0
XLL-4-59,S-1	29.2	LL-5-82	33.1
XLL-12-59,S-1	34.2	LL-6-82	34.8
LL-1-80	14.0	LL-7-82	42.6
LL-2-80	25.3	LL-8-82	25.5
LL-3-80	16.4	LL-9-82	30.3
LL-4-80	19.3	LL-10-82	17.0
LL-5-80	15.0	LL-11-82	32.3
LL-6-80	26.5	LL-12-82	15.8
LL-7-80	24.0	LL-13-82	42.7
LL-8-80	17.4		
LL-23-80	28.0		
LL-24-80	24.1		

LARCH CONE COLLECTIONS AND SEED YIELD

Our first larch cone collection was undertaken in an 18-year-old European larch planting in 1979. The cone production that year appeared to be good on the more exposed individuals. The planting was observed for cone production during the following four years but it was not until 1983 that the next good cone crop occurred.

Cones were collected from three of the same trees used in the first cone collection. Cone production per tree was comparable for the two different year's collections, but the seed yield was considerably greater in the 1983 collection. It was apparent in the 1979 collection that much of the seed remained in the cones after kiln drying. Discussions with European cooperators indicated that this has been a problem, and they suggested a mechanical treatment to break up the cones. That approach was tried on a small scale but it was rather unsuccessful. It was felt that kiln drying may have case hardened the cones and prevented normal opening. An application of heat still appeared to be needed, particularly with the European larch cones.

The seed extraction approach used in this year's cone collection was quite successful. Based on previous years' collections, the decision was made to allow the cones to ripen on the trees as late into fall as feasible. European larch cones collected early in the fall in previous collections opened with great difficulty and retained much of their seed. However, European larch cones collected late in the fall opened readily and shed most of their seed. Japanese larch had to be collected earlier to prevent seed loss while on the tree. Both species, after collection at an appropriate time, shed seed readily when placed on racks over a low temperature heat source. It appears that seed shed would progress acceptably if cones were placed on drying racks similar to those being used for other conifers. Japanese larch should not present a seed extraction problem. European larch seed is more difficult to handle, but extraction can be facilitated by delaying cone collection and by placing cones in a warm, well-ventilated area.

The cone and seed information given in Table IV is for the fall 1983 cone collections from three relatively open grown plantation trees. The seed data indicate our earlier estimates of European larch seed production were conservative; improved extraction methods have meant considerably greater seed yields.

As can be seen from the results given in Table IV, cone and seed production varied considerably from tree to tree. Seed yield ranged from 328 grams to over 1440 grams per tree. Seed extraction was undertaken over a period of time without the use of kiln drying. It is not expected that such frequent extractions will be necessary when processing cones from an operational orchard. It is hoped that a combination of air drying and a minimum exposure to kiln temperatures will allow the collection of a major portion of seed during one extraction.

TABLE IV

EUROPEAN LARCH CONE COLLECTION

October 18-20, 1983

Tree Number	Age	Cones/ Tree	Extraction Dates	Seed Weight, g	Germination Capacity[a] %	Total Seeds/ Tree	Total Seeds/ Cone
1	22	2256	Oct. 31	151	19	101,885	45.2
			Nov. 30	153	16		
			Dec. 29	197	17		
			Jan. 27	126	14		
2	22	5232	Oct. 31	350	47	234,969	44.9
			Nov. 10	111	56		
			Nov. 30	516	28		
			Dec. 29	339	27		
			Jan. 27	130	29		
3	22	1115	Oct. 31	157	59	53,299	47.8
			Nov. 10	19	47		
			Nov. 30	83	44		
			Dec. 29	36	46		
			Jan. 27	33	43		

[a]Seed was stratified 14 days, then germinated on moist filter paper.

Germination efficiency and capacity were determined for each collection date, and not unexpectedly, the germination capacity decreased with time. Germination also varied from tree to tree.

Cone collections, seed extraction, and observations of the periodicity of cone crops and frost damage will continue to be part of the larch program. Additional work needs to be directed at the improvement of seed germination, either through supplemental pollination in seed orchards or by removing a portion of nongerminating seed from seed collections. Improved germination is needed particularly for container growing operations and, although not as crucial for seedbed sowing, is still highly desirable for nursery operations.

SEED AVAILABILITY

As the larch program continues to demonstrate the potential of Larix as an additional conifer for reforestation and begins to identify the most suitable species and provenances, the demand for quality seedlings is increasing. The larch program has advocated and continues to advocate a somewhat moderate approach, believing that an organization must first familiarize itself with larch growth in the nursery or container greenhouse, with the handling of larch planting stock, and then with field establishment. Unfortunately, the pressure to provide a large number of seedlings before sufficient answers have been reached is creating the kind of problem that it was hoped could be avoided. That problem is the use of unknown seed sources and the establishment of stock on marginal sites and/or with heavy vegetative competition.

The enthusiasm, potential, and continued interest in a species for tree improvement must be tempered with a slow, cautious familiarization with that candidate. The ultimate grower must be given an opportunity to handle and establish the material but he should be urged to go slowly to avoid large scale mistakes.

We have been asked to address the availability problem of good quality seed. The larch project has as part of its goal, the acquisition of known origin seedlots to aid in the identification of those provenances best suited for the Lake States and Northeast. In the process of acquiring this needed seed it has become apparent that larch seed is often in limited supply and expensive. We were fortunate in that several cooperators in the aspen tree improvement program are also working with larch, and we have been able to acquire a steady supply of known origin seedlots but of limited amounts, often only a few ounces. This fall a larger quantity became available, and we were given a price list of the sources available (Table V). We acquired several pounds of the seed listed in Table V but were reluctant to acquire larger amounts until specific provenance performance is evaluated and until site selection and establishment techniques are developed. The use of relatively inexpensive, unknown origin seed was perceived as adequate for the initial familiarization studies but it appears that the next step is to acquire a modest amount of good quality seed. This seed has been purchased and is available to interested cooperators.

TABLE V

LARCH SEED SOURCES AND COST

Species and Origin	Cost/Kilogram, dollars
European Larch	
Sudeten	460
Wienerwald	280
South Germany	225
Lake of Constance	240
Alps (below 900 m)	460
Brenner (Austria, 1300-1500 m)	160
Japanese Larch	
Hokkaido	145
Plains	280
Mountains	315
Hybrid Larch	600

The sporadic availability of European and Asiatic sources of larch seed, along with the high value placed on this seed, tends to underscore the desirability of having our own larch seed orchards. The program will be somewhat dependent on cooperators in Europe and Asia until our own orchards begin to produce seed. The first orchard is scheduled to be planted the spring of 1985 with additional orchards to be planted in successive years.

It is intended that the first orchard be established within reasonable distance from Appleton to allow IPC personnel to visit the orchard frequently. By placing the first orchard within easy access, establishment problems can be dealt with as they arise. This first orchard will, of necessity, bear the brunt of the mistakes that any new venture encounters. Succeeding orchards will hopefully have the benefit of improved establishment techniques obtained from working with the first orchard.

LARCH NEEDLE CAST

Both the U.S. Forest Service and the University of Wisconsin have continued to monitor the needle cast disease on European larch in Iowa and Wisconsin that we reported in Project 3409 Progress Report Two. The disease is believed to be Mycosphaerella laricina (Hart.) Neg. which is reported to cause defoliation of European and Japanese larch in Europe. The symptoms are manifested by a yellowing of the needles in the lower crown during early summer followed by needle loss and often reflushing and subsequent reinfection.

Observations and spore trapping in larch stands in Wisconsin and Iowa were undertaken by the USFS and the University of Wisconsin during the past several years. Their results indicate that disease severity has continued to increase in a central Austrian source of European larch and that only a few trees of a French source of European larch remain alive. A disease survey by Robbins found that trees from Alpine sources (Austrian, French, and Italian) were most susceptible, and sources from more northern provenances (Czechoslovakia and Poland) were less susceptible. No needle cast symptoms were observed on Japanese or hybrid larch.

There is a need to be cautious in the selection of European larch seed sources to minimize the effects of the disease. Sources from France, Italy, and Austria should be used with restraint. Until more definitive screening is completed, only northern sources of European larch seed should be used. Hybrid and Japanese larch seed sources are apparently free of the needle cast problem.

The U.S. Forest Service is attempting to develop a screening method to evaluate the resistance of various sources of larch to the needle cast disease. Our intention is to cooperate with the USFS by providing seed from known origins and to subject all of the parent tree selections to this screening process when it becomes available. It is hoped that the screening method can be used as part of our parent tree selection process. The effects of the disease can be minimized by the proper selection of seed sources. Based on the present awareness of the disease problem, the first seed orchards will have only clones from the northern range of European larch. Clones from other sources will be added as their disease resistance is demonstrated.

REPLICATED FIELD PLANTINGS

MOSINEE PAPER CORPORATION

One of two replicated trials planted in 1981 was established near Gordon, Wisconsin on Mosinee Paper Corporation land. The trial is located on a sandy, dry, old-field site that had been planted to red pine, and the planting had partially failed. The site was prepared by spraying with glyphosate and plowing and disking. The stock was container grown and, in hindsight, was too succulent for outplanting. A combination of bare soil and succulent stock produced a severe problem with groundline injury that resulted in high mortality throughout the trial. Several materials had replacements planted in August, 1981, two months after the initial planting.

Frost damage to the Japanese and hybrid sources of larch was noted the following spring (1982). Observations later in the summer of 1982 indicated that most of the trees, with the exception of the Japanese larch, were recovering from the frost damage. A continuing frost problem with Japanese larch on this site is reflected in the survival data given in Table VI. In addition to the frost problem, a large number of pocket gophers have become established in the trial and have caused injury and mortality through both root feeding and aboveground feeding.

The best stems in the trial, primarily hybrid and European larch, put on up to two feet of growth (Fig. 4). The tamarack source has also done well, having the best survival, and height growth comparable to the European larch (Table VI).

Plans for the trial include replacing the Japanese larch provenance having the lowest survival with a hybrid or European larch source. Both frost and gopher damage will continue to be monitored. It is felt that the trial is now established and that given a reasonable growing season in 1984 and lessened pressure from the pocket gophers, it should be able to continue the good growth that was becoming apparent in 1983.

TABLE VI

MOSINEE PAPER CORPORATION

Replicated Larch Trial

Material	1982 Av. Ht., feet	1982 Survival, %	1983 Av. Ht., feet	1983 Survival, %
XLD-3-79	1.2	61	1.8	48
XLD-5-79	1.3	69	1.9	55
XLD-6-79	1.1	75	1.5	58
XLL-1-79	0.8	49	0.8	28
XLL-2-79	0.9	65	1.0	52
XLL-5-79	0.7	64	1.2	47
XLD-LL-1-79	1.4	93	1.9	74
XLTK-5-80	1.0	88	1.5	82

Figure 4. Two-year-old container grown European larch (XLD-3-79) growing in Mosinee Paper Corporation's replicated larch trial near Gordon, Wisconsin. The best material averages 1.9 feet. The site is a sandy, old field and has produced survival problems. Those materials that are now established are expected to continue to grow well.

POTLATCH CORPORATION

The Potlatch replicated trial was one of two trials established in 1982. The seed sources included three Japanese larch, four European larch, and one hybrid. All seedlings were grown in styroblocks by Potlatch.

The trial was planted on a cutover hardwood site that had been planted to red pine. Heavy returning grass and herbaceous competition reduced the growth and survival of the red pine. The area was sprayed with glyphosate, disked, and scarified during the two years prior to planting. The larch trial was established by planting container stock in scalped furrows.

The trial was observed this past fall at the end of two growing seasons. Survival was excellent and appeared to approach 90%. Growth on the individuals observed ranged from 10 inches to two feet with the majority averaging about 14 inches (Fig. 5). Returning vegetation was heavy and smaller trees were overtopped

Figure 5. Two-year-old container grown European larch growing on Potlatch Corporation's replicated trial near Cloquet, Minnesota. The trial was established on a cutover hardwood site by planting in scalped furrows. The trial was not measured but height, survival, and growth were good for all materials with many stems over 2 feet. Vegetation is becoming heavy, but the larch is established and should be capable of competing.

by a rank growth of grass. Although overtopped, these trees still appear capable of coming through the competition. Trees with more exposure have developed a good, balanced growth of lateral branches as well as a good, dominant leader. In comparison, overtopped trees tended to have little lateral branch development and a leader that was somewhat spindly.

At this point, the trial appears to be established and capable of overcoming the competition. The trial was not measured this year but will be measured next year.

CONSOLIDATED PAPERS, INC.

Eight sources of container grown larch were established in a trial with four replications and a randomized block design near Argonne, Wisconsin in August of 1981. The trial area is a medium quality hardwood site that had been cleared for farming. The field on which the trial was located had a dense cover of quack grass and was treated with glyphosate at the rate of 2 lb a.i./acre one week prior to planting. Vegetation control was only marginal and heavy competition developed. Glyphosate was applied again in 1982 using a directed spray and shielding the larch. The release effort was successful, and the European larch and tamarack began to recover. The Japanese larch, and to a lesser extent the hybrid larch, continued to suffer from frost damage. Despite replacements, the Japanese larch continued to have mortality and we decided to replace two of the sources with European larch. Replacements were also made in the hybrid source and one of the European sources. Frost damage was observed on September 28, 1983 from a frost that had occurred on September 23. The remaining source of Japanese larch was damaged, but no damage was noted on the European, hybrid, or tamarack sources.

Table VII gives the height and survival of the various sources. The best materials are two sources of European larch (XLD-3-79 and XLD-5-79) and the tamarack source (XLTK-5-80). Growth of the best individuals was 1-2 feet with good caliper and lateral branching (Fig. 6). The tamarack has done quite well on this site and will be of continuing interest as the planting develops. The overall vigor of the trial was such that most materials should be well above the grass competition by next fall.

TABLE VII

CONSOLIDATED PAPERS

Replicated Larch Trial

	1981		1982		1983	
Material	Av. Ht., feet	Survival, %	Av. Ht., feet	Survival, %	Av. Ht., feet	Survival, %
XLD-3-79	1.0	100	1.6	88	2.9	86
XLD-5-79	0.9	99	1.4	93	2.4	99
XLD-6-79	0.9	100	1.2	74	1.9	70
XLL-1-79	0.9	89	1.1	100	1.6	77
XLL-2-79	0.9	96	0.5	6	--[a]	--
XLL-5-79	0.7	99	0.6	22	--	--
XLD-LL-1-79	1.2	99	1.1	52	1.8	99
XLTK-5-80	0.9	100	1.5	94	2.5	97
XLD-1-81	--	--	--	--	1.9[b]	99
XLD-5-82	--	--	--	--	0.7	100

[a]Replaced with sources XLD-1-81 and XLD-5-82.
[b]First year growth and survival.

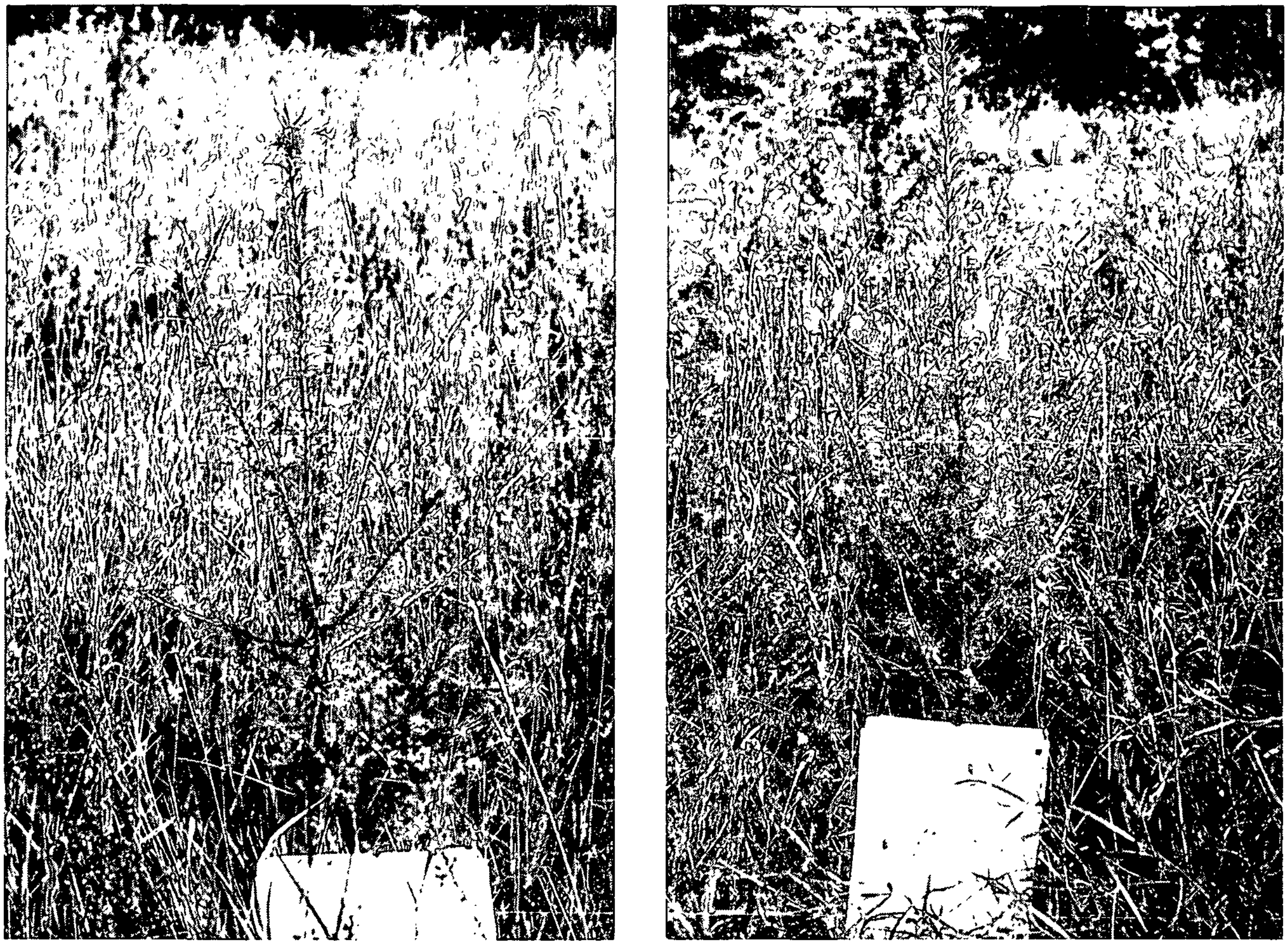

Figure 6. Three-year-old container grown tamarack (left) and European larch (right) growing in Consolidated Papers' replicated larch trial near Argonne, Wisconsin. The European larch averaged 2.9 feet, and the tamarack averaged 2.5 feet after a difficult establishment period on an old field.

SCOTT PAPER COMPANY

All of the replicated trials, with the exception of the Scott trial, have had container grown sources of planting stock. The 2-0 bareroot stock provided for this trial was grown at the IPC nursery at Greenville, Wisconsin and shipped to Maine for planting the spring of 1982. The material included four sources of European larch, two sources of Japanese larch, one source of hybrid larch, and one local source of tamarack grown in Maine.

The planting site had been under cultivation and was disked prior to planting. Vegetative competition developed to a greater degree than anticipated, and a directed spray of glyphosate was applied in 1983. Some mortality has been attributed to the glyphosate treatment. Although care was taken to shield the trees, apparently a small amount of herbicide came in contact with laterals. Overall survival, however, has been good for all materials.

Table VIII presents the growth and survival data from the first two growing seasons. The best materials are the hybrid larch source, XLD-LL-1-79, and the Japanese larch source XLL-3-79. XLL-3-79 is a seed source from a clonal seed orchard containing plus tree selections from native Japanese larch stands. The stands from which the selections were made had been the source of seed for the international Japanese larch provenance trials planted in 1959.

TABLE VIII

SCOTT PAPER CO.

Replicated Larch Trial[a]

Material	1982 Av. Ht., feet	1982 Survival, %	1983 Av. Ht., feet	1983 Survival, %
XLD-1-79	1.2	95	2.2	95
XLD-2-79	1.4	81	2.5	81
XLD-3-79	1.7	96	2.7	97
XLD-6-79	1.4	90	2.5	90
XLL-2-79	1.2	84	2.5	84
XLL-3-79	1.6	83	3.2	83
XLD-LL-1-79	1.8	89	3.3	90
Tamarack	<1.0	84	1.3	83

[a]Measurements and data provided by David Maass.

Height growth was reported as being quite good for a number of individuals within each source. At least one individual in each source had leader growth of 2 feet. An individual in the XLL-3-79 source had height growth of over three feet. The trial appears to be established, but an additional treatment of herbicide may be necessary if vegetation conditions next spring warrant it.

MEAD CORPORATION

Two trials were planted the spring of 1983 on old field sites approximately 40 miles east of Escanaba, Michigan. The trials were to test three sources of container grown Japanese larch, three sources of European larch, and one source each of hybrid larch and tamarack. The site was sprayed with glyphosate in midsummer of 1982 and was followed by burning and disk trenching in the fall. After planting the following spring, a prolonged, 7-week drought produced extensive mortality and the trials were lost. Replacement stock was not available, and as a consequence the trials were terminated.

DEMONSTRATION FIELD PLANTINGS

THILMANY PULP & PAPER COMPANY

Four small plantings of Japanese larch were established by Thilmany Pulp & Paper Company with members of their tree farm program the spring of 1982. Three plantings were put in near Waupaca, Wisconsin on abandoned farm fields and one on a small clearing that appeared to have served as a landing for a pulpwood operation. The soils ranged from sand to loamy sand, and all sites tended to be quite dry.

Two of the plantings are on poor quality sites and have had considerable competition problems from grasses and damage from voles. Coupled with drought conditions, growth and survival have been minimal. These two sites are pine sites and are better suited to red pine and/or jack pine.

A third planting was put in on better soils with reasonable moisture availability. Heavy grass competition and deer and rabbit browsing, however, reduced survival. Growth of the surviving stems was quite good with 12-30 inches on most individuals.

The fourth planting had the best growth and survival (Fig. 7). The site has better moisture availability and heavier soils (loamy sand-sandy loam). Grass competition is present but the growth of the grass was not as rank as on the other three sites. Growth on the best stems was 3.5 feet with most stems producing one to two feet of growth. There was deer browsing, affecting 16% of the stems when measured the spring of 1983, but no rodent or rabbit damage was noted.

Two of the four sites were too low in site quality for good larch growth. The remaining two sites had heavier soils and better moisture availability and produced the best growth. Grass competition was the major factor reducing survival on all sites, particularly on the marginal sites.

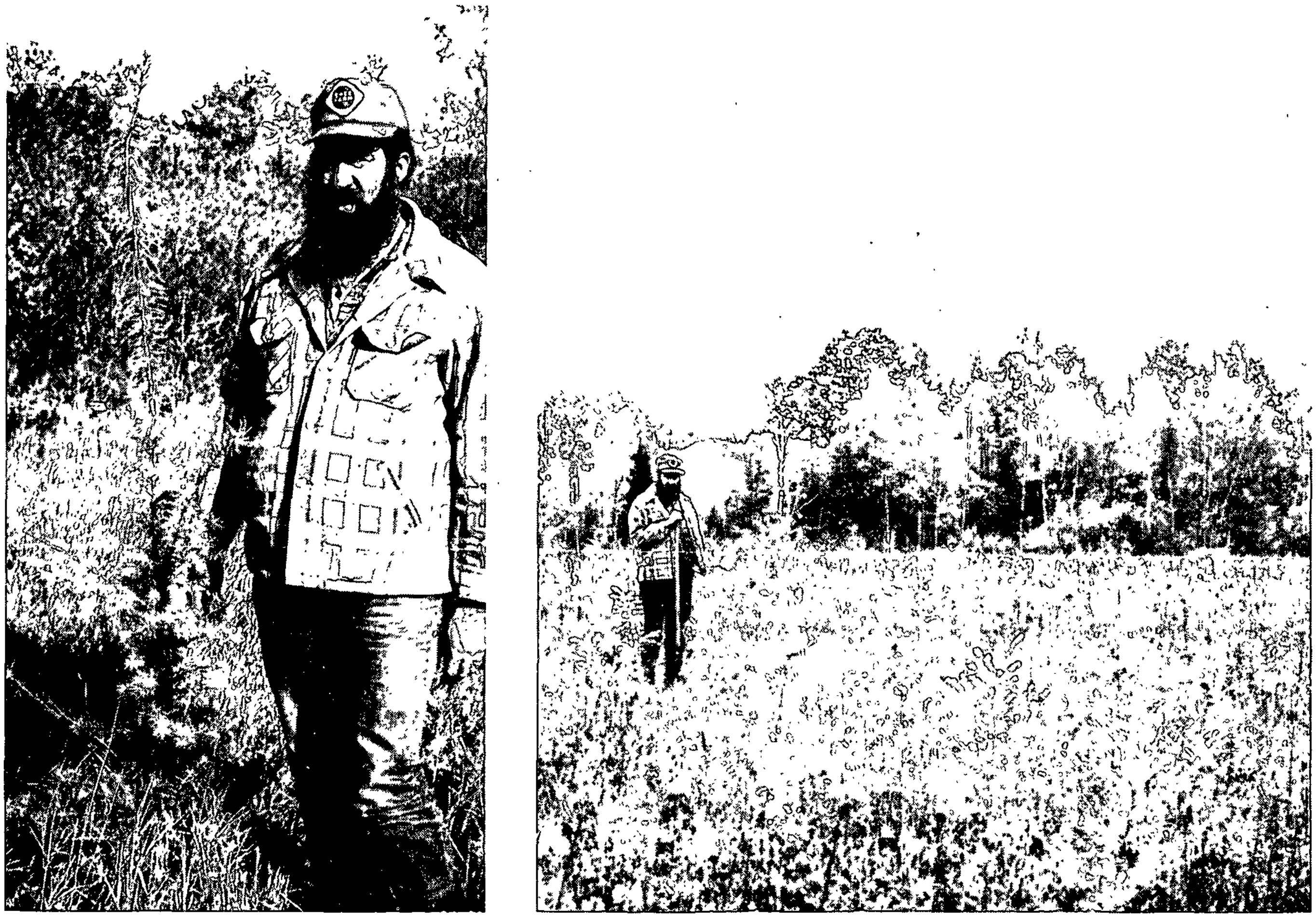

Figure 7. Two-year-old bareroot Japanese larch established by Thilmany Pulp & Paper with their tree farm cooperators, near Waupaca, Wisconsin. All of the sites had heavy grass competition which contributed to low survival in those plantings on dry, sandy sites. The two plantings shown are on loamy soils with better moisture availability. One of the best stems (left) was over 6 feet, and one of the better plantings (right) had good survival with growth averaging 1.5-2.0 feet.

CONSOLIDATED PAPERS, INC.

In June of 1981, a small replicated trial was established on Consolidated Papers, Inc. lands near Winchester, Wisconsin to evaluate the effect of four herbicides on planted, container grown hybrid larch. The planting was put in the summer before on a clearcut aspen-balsam fir site. The returning aspen suckers were more dense than anticipated, and it was apparent the planted larch would benefit from release. There were no release chemicals available that would leave the larch uninjured, so a trial was initiated to look at the effect of Simazine, Roundup, Velpar liquid, and Krenite applied over the top of the larch. It was felt that the competing vegetation would intercept most of the herbicide applied in the case of Roundup and Krenite and that by going to low levels of Velpar (0.5 and 1.0 lb/A) control would be sufficient to afford release without extensive injury to the larch. Simazine had been used in establishing larch without injury and was known to have an adverse effect on aspen, the major competition problem with this planting. For that reason, it was applied as a release chemical.

Table IX gives the relative amount of the various vegetation components during the 2 years following treatment and the average height and survival of the hybrid larch within the treatments. Height growth and survival were adversely affected by the Krenite and the 1 lb Velpar treatment but were not affected by the other treatments. Although the Simazine treatment did not have the desired effect on the aspen suckers, it is still felt to be a valid approach. Apparently, the Simazine treatment was applied too late in the spring to have had effect on the aspen or on the grasses.

TABLE IX

WINCHESTER HYBRID LARCH HERBICIDE RELEASE TRIAL
AREA PLANTED 1980, TREATMENTS APPLIED 1981

	Treatment	Year	% of Ground Cover						Hybrid Larch[a]	
			Woody Plants	Broadleaf Weeds	Grasses	Open	Ferns	Raspberry	Av. Ht., ft	Survival, %
1	Control	1982	38	18	40	3	--	--	1.9	82
		1983	27	8	50	--	15	--	2.8	76
2	Simazine 2 lb	1982	40	15	43	3	--	--	1.8	89
		1983	30	13	39	3	10	4	2.5	89
3	Roundup 2 lb	1982	3	48	17	32	--	--	1.5	67
		1983	2	58	35	2	3	--	2.4	65
4	Velpar L	1982	20	12	62	7	--	--	1.5	63
	1/2 lb	1983	14	20	54	--	12	--	2.3	63
5	Velpar L	1982	8	12	65	13	<2	--	1.3	25
	1 lb	1983	7	27	38	5	20	1	1.9	28
6	Krenite 2 gal	1982	<1	12	20	68	--	--	0.8	24
		1983	<1	25	70	7	--	--	1.5	21

[a]An analysis of variance was run on the above data. There were highly significant differences in survival but no significant differences in height growth.

Table IX illustrates the changes in the relative amounts of each of the vegetation components in reaction to the treatments. Four of the treatments removed the woody competition but then shifted the competition to either the broadleaf or grass component. The Krenite treatment was expensive but very effective during the first year following treatment. However, it resulted in a major invasion of grasses during the second year.

It does appear that, on those sites where woody competition is the major detriment to establishment, it can be controlled by an application of Roundup. It should be pointed out that on this site, the competition completely overtopped the planted stock and, therefore, intercepted most of the herbicide before it reached the stock. Had the site been more open, more planting stock mortality could have been expected. As mentioned previously, the Simazine treatment, particularly for the control of aspen and grasses, should have had more of an effect. Much of the planting on which this study was superimposed is still having competition problems, primarily from aspen and grasses. Tentative plans call for another treatment of Simazine at the appropriate time. Figure 8 illustrates one of the better individuals on the site after 4 growing seasons. It is felt that had competition been controlled, a greater number of stems would have had similar growth.

Figure 8. One of the best 4-year-old container grown hybrid larch growing on Consolidated Paper's lands near Winchester, Wisconsin. The area is a cutover aspen-balsam fir site that is producing considerable competition from aspen suckers.

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

In May of 1979 a conversion planting of primarily European larch with a small amount of Japanese larch was put in on state owned land near Covington, Michigan. The site has a soil texture of sandy loam with a considerable number of stones and has acceptable moisture availability. The area had a medium quality hardwood stand on it before cutting. The planting stock was 2-0 bareroot and was quite large, requiring on-site pruning to facilitate planting. The unfortunate condition of the stock contributed considerably to the mortality that occurred after planting. Frost damage was noted on both Japanese and European larch in successive years and also contributed to the low survival.

The individuals shown in Fig. 9 are in a pocket of good survival and are indicative of what could have been expected. An interesting point about the individuals shown is that they are Japanese larch and doing considerably better than the European larch. Japanese larch is not expected to do well in areas of late and early frosts but this source is doing surprisingly well. However, caution is still urged when attempting to plant Japanese larch that far north.

Figure 9. Five-year-old Japanese larch planted by the Michigan DNR on a medium quality hardwood site near Covington, Michigan. It is not recommended that large-scale planting of Japanese larch be undertaken in frost prone areas. This particular planting was put in with primarily European larch, but stock problems and frost damage have considerably reduced survival.

MICHIGAN TECHNOLOGICAL UNIVERSITY

In the spring of 1983, approximately 2000 bareroot larch seedlings grown at the IPC nursery were available for outplanting. The stock included five provenances of *Larix decidua*, four *L. leptolepis*, and one container grown hybrid larch source. The number of seedlings per source was small, but it was hoped that a replicated trial could be developed using the available material. Michigan Tech had a clear-cut, poor quality northern hardwood site on which they were interested in evaluating the performance of larch. To that end, a replicated trial was planted utilizing ten of the larch sources. Survival was good after the first year with growth of the better individuals over one foot. Average height growth was nearer 8-10 inches. Competition from bigtooth aspen suckers and broadleaf weeds is developing, and there are plans to release the larch with a directed spray of Roundup. Figure 10 illustrates one of the better individuals. The site is typical of where larch is expected to fit in a planting program. When planted on good pine sites and poor to medium quality hardwood sites, larch will outgrow all of the conifers now being planted on those sites.

Two other conversion plantings established by Michigan Tech were also observed last fall. Figure 11 illustrates individuals from those plantings. One of the plantings was established on a poor quality hardwood site and is now four years of age. Although survival is down, the stocking appears to be satisfactory. Height of the better stems is over 10 feet. The major competition problem is from pin cherry, but the larch appears to be competing well. The climbing false buckwheat that had been observed in this planting previously and was of concern, was not as prevalent this year and is not expected to create further damage.

Figure 10. A Sudeten source of European larch (XLD-1-81) in a replicated trial planted by Michigan Technological University. The trial is on a poor quality hardwood site in the Baraga Plains near L'Anse, Michigan. Growth and survival were good after the first year, but returning bigtooth aspen suckers may need to be controlled during the next growing season.

The second, four-year-old European larch planting observed is on a site with a gradation of site quality. The growth pattern and survival of the larch on this site markedly reflect that gradation. The soils on the poorer part of the site are sands and have a ground cover of grasses, lichens, scattered cherry, and poor-quality aspen. The survival of the larch is very poor, and those few survivors that were noted had poor vigor and total heights of only one to three feet. As the soil and site conditions changed, the survival and growth increased. Vegetative competition also increased, primarily from pin cherry. Bear damage to the cherry, however, is of some assistance to the larch. The best individuals were over 8 feet, but this past year's leader growth indicates that most of the survivors are now established and growing well. This particular planting presents an interesting study of contrast and will be included as a stop in the planned fall field meeting.

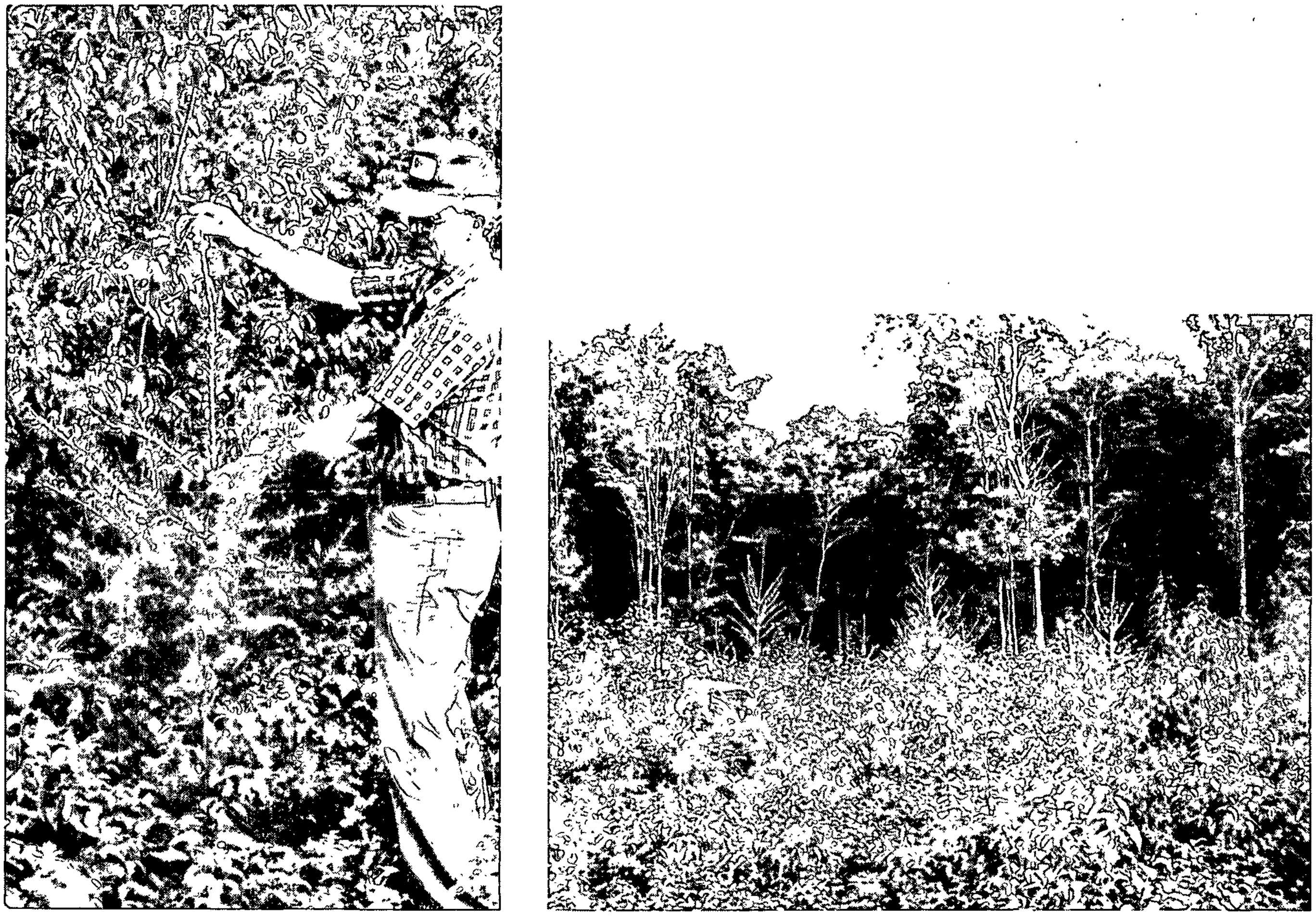

Figure 11. Two four-year-old European larch conversion plantings established by Michigan Technological University in Upper Michigan. The planting on the left was put in on an area with a range of site quality that was reflected by the growth and survival of the larch. The planting on the right was put in on a poor quality northern hardwood site and has done well despite heavy competition from pin cherry. The best individuals were over 10 feet.

OTHER PLANTINGS

Additional larch plantings have been put in by a number of cooperators on a wide range of sites. All of these plantings are being observed as they develop.

One of these plantings was put in by Consolidated Papers using container grown European larch. This 20-acre plantation failed shortly after planting. No apparent cause could be determined. The site was replanted and the stock, after the first growing season, has good survival and growth of 6-10 inches (Fig. 12). This particular planting will be used for a replicated herbicide release trial to be established this spring.

Figure 12. A one-year-old container grown European larch planted on Consolidated Papers' lands near Rhinelander, Wisconsin. A complete planting failure on this site the year before was followed by replanting and good survival. The larch shown is about 18 inches in height.

Potlatch Corporation has put in several small larch plantings, utilizing their own container grown stock. Two of these plantings were visited last year, and both are doing well. The planting illustrated in Fig. 13 is three years old and was considered only a marginal success. Observation this past fall indicated that the material is doing considerably better than anticipated. Leader growth was 2-4 feet for the best individuals and lateral branch development was good for most individuals. The site had been mechanically prepared with much of the slash pushed into windrows. Competition is primarily from grasses and is not expected to be much of a factor given the present condition of the planting. There are individuals in the planting that have a bushlike form with no dominant leader. This has been reported

Figure 13. Three-year-old container grown European larch growing near Cloquet, Minnesota on Potlatch Corporation lands. After a slow establishment period, much of the larch stock put on good height and lateral growth this past year.

by other larch growers but comprises only a small portion of the planting and should not have a significant effect on stocking.

Mead Corporation has also put in several plantings but has not had good success in establishment. A combination of factors, primarily grass competition, has contributed to their plantation failures. Those plantings put in last year were subjected to a prolonged drought period whose effects were increased by grass competition. An earlier planting was lost to meadow voles that traveled scalped planting furrows.

The Wisconsin Department of Natural Resources has also been establishing larch plantings in several locations around the state. The best plantings continue to be those on the Coulee Experimental Forest near La Crosse, Wisconsin. The forester on that forest is interested in establishing other species of larch and will be planting Japanese larch and hybrid larch this spring. There are also plans to establish a small replicated trial with IPC, testing the efficacy of two sources of mycorrhizae on Japanese larch. A bareroot replicated trial with eight provenances of larch will also be established on the Northern Highland State Forest, near Boulder Junction, Wisconsin in 1984.

Blandin Paper Company, although not a member of Project 3409, did put in a small demonstration planting of 8 provenances of larch the summer of 1982. It was originally intended to use the material for a replicated trial, but an insufficient amount of container planting stock was available. Instead, the materials were planted in rows with the provenance identity maintained. Observation this past year indicated growth and survival are good, but returning aspen suckers and broadleaf weeds may produce competition problems. The planting will continue to be observed, and although a nonreplicated planting, it is expected to provide useful information.

WOOD QUALITY EVALUATION

SELECTED TREE DATA

Wood quality evaluation continues to be an important aspect of the larch tree improvement program. Obviously it would be highly undesirable to select, propagate, and begin producing seed for large-scale plantings, only to find serious wood property deficiencies. From the pulp and paper point of view, wood density (specific gravity), fiber length, and extractives (alcohol-benzene and hot-water) are considered to be important wood properties. Equally important, selecting trees for these properties will very likely have beneficial effects on the wood quality of the trees if used for solid wood products.

With the need to be sure that adequate wood quality is maintained, the establishment of base lines for the evaluation of selected trees is under way. The procedure used has been to measure the wood properties of selected trees and trees harvested for other purposes and add these data to our base-line information as they become available.

Specific Gravity

The specific gravity values used in comparing parent trees are based upon ovendry weight/green volume measurements using two breast high 10-mm increment cores from each tree. Although complete cores are also used in measuring selected tree specific gravity, comparisons between parent trees are based on rings 14-16. For most of the trees, except those which are over 25 years of age, rings 14-16 are located in the sapwood and contain only small amounts of extractives. For trees older than 25 years of age, extractive levels should be taken into consideration when evaluating the specific gravity of individual trees. Table X, which compares the wood properties of Japanese and European larch, illustrates the modest wood density advantage of European larch and gives the variation encountered among individual trees.

TABLE X

BASE-LINE WOOD QUALITY VALUES FOR JAPANESE AND EUROPEAN LARCH

Wood Property	Japanese Larch	European Larch
Specific Gravity		
Age 15	0.390 (28)[a]	0.428 (37)
$s/\sqrt{n}$	0.008	0.006
	*****	
Fiber Length		
Age 15	3.2 (28)	3.0 (37)
$s/\sqrt{n}$	0.07	0.05
	*****	
Extractives		
Alcohol-benzene, %	3.5 (28)	2.9 (37)
$s/\sqrt{n}$	0.18	0.22
Hot water, %	5.8 (28)	6.2 (37)
$s/\sqrt{n}$	0.34	0.37

[a]Number in parentheses gives the number of trees used in obtaining the indicated means.

Fiber Length

Fiber length measurements were made using the same breast high increment core samples that were used for specific gravity. Fiber length measurements were made on rings 11-15 and on 14-16 by projecting and measuring 600+ fibers (tracheids) for each sample. The data obtained on selected trees were used to establish preliminary base-line values for comparing parent trees. This age-15 information is summarized in Table X. To better visualize how a newly selected tree compares with the age-15 base-line information from earlier selected trees and trees used in pulping studies, Fig. 14 was prepared. Plotting the value for a newly evaluated tree on the base-line figure provides an appropriate basis for comparison. When trees are marginal in other important characteristics (growth rate, form, potential disease problems, etc.), lower-than average fiber length may result in elimination of a selected parent tree from the program. Our data to date indicate that age-15 fiber length of Japanese larch is a little longer than European larch (3.2 mm vs. 3.0 mm). The differences between species appear real, and it does not appear possible to combine the data for the two species and establish a single base line.

Extractives

Extractives levels are important because they influence specific gravity values, pulp yield, and bleaching chemical requirements (particularly hot-water extractives). Alcohol-benzene extractives and hot-water extractives were determined on the interior ten rings of breast high 10-mm increment core samples and as such represent values for heartwood for trees of age 15 or greater. TAPPI Method T 204 os-76 was used for alcohol-benzene extractives, and a modification of the same method was used for hot-water extractives. Separate samples were used for each determination, and the results obtained were expressed as the

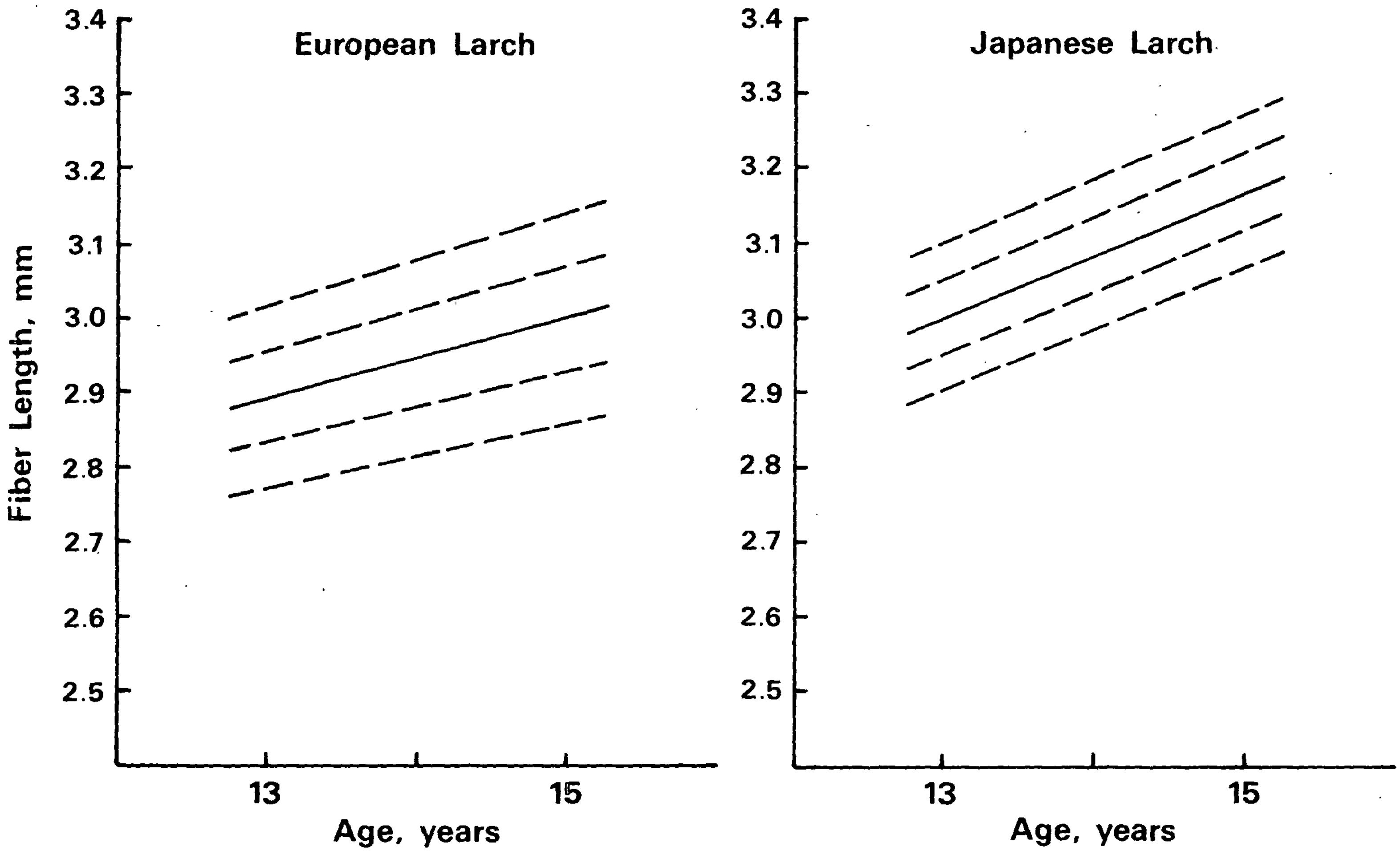

Figure 14. Fiber length base-line values for evaluating European and Japanese larch parent trees. Comparison made on breast height increment core samples. The solid line is the mean value and the dashed lines are one and two standard deviations ($s\bar{x}$) above and below the means.

percent dry weight. Table X summarizes the extractives data. Japanese larch has a higher level of alcohol-benzene extractives and about the same level of hot-water extractives as European larch. The levels reported continue to be less than reported for older, slow-growing trees. There also appears to be some evidence that extractive levels in heartwood are age dependent (increase with tree age), and some method of adjusting for tree age may be required when comparing parent tree extractive levels.

USE OF LARCH IN SOLID WOOD PRODUCTS

Introduction

Information in the literature indicates European and Japanese larch have been successfully pulped in Europe and Japan by the kraft, bisulfite, and two-stage stora process. Literature values based upon wood quality evaluation of older, relatively slow-growing trees indicate that "larch" pulps could be expected to produce low-yield pulps of appropriate fiber dimensions that are difficult to bleach and refine. Preliminary observations of wood samples from rapid-growing, plantation-grown trees demonstrated that younger trees (15-25 years) can be expected to have quite different chemical and fiber properties than older, slow-growing trees (1-3).

Results of kraft pulping studies conducted under Project 3409 have demonstrated that 18 to 23-year-old European, Japanese, and hybrid larch can be successfully pulped and, when compared with 55-year-old jack pine, had higher pulp yields and pulp strengths that were in most instances superior to jack pine (*Pinus banksiana*). Subsequent preliminary comparisons with red pine (*Pinus resinosa*) indicate "larch" has an even greater superiority over plantation-grown red pine, when compared at similar ages.

There is also a need from the forest management point of view to consider the usefulness of European, Japanese, and hybrid larch in solid wood products, as contrasted to paper and paperboard. The underlying reason is that under most "plant and harvest" forest management situations, the economics work out much better when plantings are first thinned for fiber (and energy) and the remaining crop trees carried for a number of additional years and harvested for use in solid wood products.

The comments that follow, although not a comprehensive review, attempt to bring together most of what is known about the use of *Larix* species for solid wood products and reconstituted wood products. Quite surprisingly there has been only a minor amount of information published on native species of larch.

Earlywood Strength Comparisons

One of the earliest comparisons of the strength properties of plantation grown conifers was made by Olson *et al.* (4) and included European larch grown in Connecticut. The trees evaluated were grown on similar sites, and the authors further compared plantation grown trees with data on forest grown trees of the same species. Table XI lists the species, age, and average tree size of the material used in the comparison. It is of particular interest that the European larch was the youngest, yet was the largest in size by a considerable margin. A partial list of strength properties compared are summarized in Table XII.

There are two points of interest that should be considered when reviewing data from Table XII. One is the overall favorable strength values of plantation grown European larch when compared with the other conifers considered satisfactory for use in solid wood products. The second point, which was pointed out by Bendtsen (5), is that red pine had the largest reduction in mechanical properties when comparing plantation-grown trees with natural forest-grown trees. Average modulus of rupture (MOR) was 32% lower, modulus of elasticity (MOE) 39% lower, and compression parallel to the grain was 48% lower.

TABLE XI

DESCRIPTION OF TREES EVALUATED[a]

Species	Number Trees	Average Age from Seed	Av. d.b.h., inches	Av. Height, feet
European larch	23	30	11.4	47
Jack pine	13	31	7.5	39
Red pine	9	40	7.6	44
Scotch pine	14	35	8.7	44
E. white pine	25	36	9.2	44
Norway spruce	12	34	8.0	41

[a]From Olson, *et al.* (4).

Bastien and Keller (6), in an interesting study compared the wood density and strength properties of wood from 15-year-old European larch (*Larix decidua*), Japanese larch (*L. kaempferi*), and a hybrid larch (*L. eurolepis*). Table XIII summarizes several of the mechanical properties investigated. The hybrid larch gave the best strength values even though the density was intermediate. The values of these three sources of larch indicate that despite their younger age, they have mechanical strengths comparable to the values reported by Olson *et al.* (4). In another interesting and related study, Sachsse, Wulf and Müller-Schönan (7) demonstrated there were significant differences in specific gravity, percent latewood, fiber length, and bending and impact strength of 22 clones of *L. leptolepis* growing in Germany. The demonstrated differences were interpreted to

TABLE XII

BASIC STRENGTH PROPERTIES OF SIX PLANTATION-GROWN CONIFERS, OLSON *et al.* (4)

Species	Specific Gravity[a]	Rings per Inch	Weight per Cubic Foot,[b] lb	Static Bending: Stress at Proportional Limit,[b] psi[c]	Static Bending: Modulus of Rupture,[b] psi	Static Bending: Modulus of Elasticity,[b] 1000 psi	Compression Parallel to Grain: Stress at Proportional Limit,[b] psi	Compression Parallel to Grain: Maximum Crushing Strength,[b] psi	Compression Perpendicular to Grain: Stress at Proportional Limit,[b] psi	Hardness: End,[b] lb	Hardness: Side,[b] lb	Shear Parallel to Grain, psi	Toughness,[d] inch lbs
European larch													
Plantation	0.45	5	30	4300	8500	1010	2380	4280	890	800	610	1510	127
Forest	0.50	8	33	5700	11400	1390	3400	6370	780	1100	920	1455	--
Jack pine													
Plantation	0.43	7	29	5400	8700	1170	2530	4180	720	780	620	1410	108
Forest	0.46	7	30	5000	7900	1200	--	5400	820	660	580	1120	--
Red pine													
Plantation	0.39	7	25	4200	8500	1100	2550	3880	680	560	440	1320	109
Forest	0.51	22	34	9400	12500	1800	5330	7340	830	670	580	1230	--
Scotch pine													
Plantation	0.44	7	30	5700	9400	1390	3310	5030	670	640	500	1340	107
Forest	0.49	9	32	6700	11700	1600	3240	6250	750	840	850	1470	--
E. White pine													
Plantation	0.32	6	21	4100	6800	955	2620	3610	440	420	310	790	--
Forest	0.37	13	25	6000	8800	1280	3680	4840	550	500	400	860	--
Norway spruce													
Plantation	0.37	6	25	5200	8500	1440	3390	4540	530	550	430	720	--
Forest	0.40	--	27	6800	11100	1710	--	--	--	--	--	924	--

[a]Based on ovendry weight and ovendry volume.
[b]At 12% moisture content.
[c]psi = lb per square inch.
[d]At moisture content ranging from 9 to 20%.

mean heritability was high and there were good possibilities for genetic improvement of the properties listed. Sindelar (8), in a study similar to that of Bastien and Keller, compared the chemical and strength properties of a number of species of larch, including Siberian, Dahurian, and European larch. Sudeten larch, a source of European larch, was characterized by rapid growth and suitable mechanical properties for use in solid wood products.

TABLE XIII

MECHANICAL PROPERTIES OF WOOD AS MEASURED ON STANDARDIZED SAMPLES[a]

Species	Breaking Stress,[b] psi	Elastic Modulus,[b] psi x 10^3	Breaking Stress,[c] psi	Density at 12% Moisture	Basic Density
Larix decidua	10,390	1,062	5,930	0.491	0.413
Larix kaempferi	10,310	1,015	5,350	0.431	0.362
Larix eurolepis	11,840	1,353	6,190	0.479	0.402

[a]From Bastien and Keller (6).
[b]During static bending.
[c]During axial compression.

Composite Board

There is a large number of research papers of Russian, Japanese, and Korean origin that describe research underway and the usefulness of larch species in particle board (9,10,11,12)*, fiberboard (13,14), gypsum board (15,16,17)*, and cement board (18,19,20). The studies involving particle board include research which describes the use of bark as a binder and particle board produced without binder (21,22,23). The Russians appear to be making the greatest use of larch and have classified larch particle board as a high strength board (9).

*Only several of 30-40 references in this area.

Studies which described research underway on gypsum and cement board indicate considerable use is being made of larch for this purpose in Japan and Korea. The most common problem being researched is associated slow "imperfect" setting or hardening of the board, apparently because of chip extractive levels. Several treatments, including oil pretreatment of chips, were effective in curing the problem (24,25). Several species of larch, including tamarack (26), are being or have been shown to be suitable for waferboard. Doucet *et al.* (27), in comparing Japanese, European, and tamarack growing in Canada for use in waferboard, reported "the wood of the genus *Larix* from plantation shows an excellent aptitude for manufacture. The mechanical readings obtained widely exceed standard requirements. Of the tree species observed, Japanese larch seems to show the most promise."

Lumber and Structural Uses

There is evidence in the literature of the suitability of *Larix* species in lumber, structural timbers, and for poles. Mill (28) and Shortle *et al.* (29), for example, described the use of Larix species for poles. Sindelar (8) in a comparison of Siberian, Dahurian, Japanese and European larch indicated that European larch, which was being planted because of resistance to industrial emissions, had good physical and mechanical properties and, in addition to being used for furniture, was suitable for pulping. Stump *et al.* (30) described the satisfactory use of plantation-grown hybrid larch (and several other conifers) in laminated veneer lumber. Similarly, McKenna and Smith (31) described the evaluation of laminated veneer lumber joined with metal plate connectors. European larch outperformed white pine, red pine, and red spruce and had a normal design load that was 94.3% of southern pine.

Plywood

Not only has larch been used in composite board, there is evidence *Larix* species have been used in embossed wood (32,33) and also for plywood. Taguchi (34) described the experimental use of Siberian larch in the manufacture of plywood. There is also evidence that Japanese larch is being made used in plywood (35) but that some problems have been encountered in the use of Japanese larch for lumber and plywood because of spiral grain (36). Similarly, Hyun (37) indicated Korean sources of Siberian larch are not widely used for lumber and plywood because of spiral grain.

Molded Wood Products

Another use the Russian wood product industry is making of larchwood is for molded wood products. One approach described by several researchers was the production of binderless board and other molded products by the use of high temperature and pressure. The resulting products had increased water resistance, hardness, and static bending strength (38,39,40). Molded products with anti-friction properties were produced from larchwood particles with pressures of 400 kg/cm^2, a temperature of 190°C, and pressing time of 1 min/mm thickness (41). The resulting product is recommended as a substitute for metal parts. Another approach, which has been known for some time and has been used with larchwood and a number of hardwood species, is the use of ammonia to plasticize wood. Properly treated species like aspen, birch, and larch became harder than oak, have improved texture, and are expected to find wide use in furniture, machine parts, construction hardboard, etc. (42).

PLANS FOR 1984-85

A review of our plans for the coming year indicate that the overall level of activity will be even higher than this past year. We expect to add eight to ten new parent trees to the program and work out an exchange procedure with cooperators in Europe and Canada that would provide us with an additional 20 valuable parent trees.

Grafting of newly selected parent trees and the grafting of twenty selected European larch clones for use in the first (1985) seed orchard are expected to require that we make 1100 to 1220 grafts this spring. At present there are 70 larch clones in the scion arboretum, and 36 additional clones are scheduled for field planting this spring.

Work with herbicides this year will include a cooperative trial with Michigan Technological University and a herbicide release trial with Consolidated Papers. Also, plans are nearly completed for a replicated bare-root planting of larch and larch hybrids by the Wisconsin DNR on the Highland State Forest. A small field planting is also planned in southeastern Wisconsin using mycorrhizae infected seedlings.

Another important aspect of this year's activities include the office, field, and nursery work associated with organizing the conversion plantings that are planned for 1985. These plantings, as it now stands, will compare hybrid larch growth for several site preparation methods, on three soils (geographic locations) and container _vs._ bare root planting stock.

ACKNOWLEDGMENTS

The authors of this report are indebted to Robert Arvey and John Lorenz for their assistance with grafting, nursery and field trial maintenance, field measurements, and all the various wood and plant material collections. We also wish to acknowledge the assistance of the Institute's Fiber Science Group for fiber dimension measurements, the Analytical Chemistry Group for lignin and extractives measurements, Becky Dietzen for her help in correspondence and record keeping, and Betty Dorman of the Editorial and Publications Department for her patience and struggles during the typing and correcting of this report. Appreciation is also expressed to the various company foresters and cooperators for their willingness and assistance in establishing test trials. We particularly want to acknowledge the assistance of David Maass of Scott Paper in parent tree selection and scion collection and Miles Benson and the Consolidated Paper's staff at Rhinelander, Wisconsin for the use of their larch plantings and assistance in evaluating herbicides.

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APPENDIX

TABLE XIV

EUROPEAN LARCH PARENT TREE SELECTIONS
SEED ORIGIN

Material	Origin	Distribution Group[a]	Cooperator and Location
LD-10-79	Styria, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-11-79	Styria, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-12-79	Styria, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-1-80	Breslau, Poland	Sudeten	Iowa Conservation Commission, McGregor, IA
LD-2-80	Breslau, Poland	Sudeten	Iowa Conservation Commission, McGregor, IA
LD-3-80	Wroclaw, Poland	Sudeten	Iowa Conservation Commission, McGregor, IA
LD-4-80	Breslau, Poland	Sudeten	Iowa Conservation Commission, McGregor, IA
LD-5-80	Styria, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-6-80	Styria, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-7-80	Styria, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-8-80	SSUI[b]	Alpen	Wisconsin DNR, LaCrosse, WI
LD-9-80	SSUI[b]	Alpen	Wisconsin DNR, LaCrosse, WI
LD-10-80	SSUI[b]	Alpen	Wisconsin DNR, LaCrosse, WI
LD-11-80	Tirol, Austria	Alpen	Wisconsin DNR, LaCrosse, WI
LD-12-80	Rundforbi, Denmark	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-13-80	Rundforbi, Denmark	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-14-80	Rundforbi, Denmark	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-15-80	Rundforbi, Denmark	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-16-80	Zagnansk, Poland	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-17-80	Zagnansk, Poland	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-18-80	Unknown	Unknown	U.S. Forest Service, Rhinelander, WI
LD-19-80	Nodebo, Denmark	Sudeten[b]	U.S. Forest Service, Rhinelander, WI
LD-20-80	Kronborg, Denmark	SSUI[b]	U.S. Forest Service, Rhinelander, WI
LD-21-80	Palsgaard, Denmark	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-22-80	Nodebo, Denmark	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-23-80	SSUI[b]	SSUI	Hammermill Paper Co., Warren, PA
LD-24-80	SSUI[b]	SSUI	Hammermill Paper Co., Warren, PA
LD-25-80	SSUI[b]	SSUI	Hammermill Paper Co., Cattaraugus, NY
LD-26-80	SSUI[b]	SSUI	Hammermill Paper Co., Warren, PA
LD-27-80	SSUI[b]	SSUI	Hammermill Paper Co., Warren, PA
LD-28-80	SSUI[b]	SSUI	Hammermill Paper Co., Mina Hollow, PA
LD-29-80	SSUI[b]	SSUI	Hammermill Paper Co., Mina Hollow, PA
LD-30-80	SSUI[b]	SSUI	Hammermill Paper Co., Mina Hollow, PA
LD-1-81	Rundforbi, Denmark	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-2-81	Zagnansk, Poland	Polen	U.S. Forest Service, Rhinelander, WI
LD-3-81	Aroretet, Denmark	Unknown	U.S. Forest Service, Rhinelander, WI
LD-4-81	Palsgaard, Denmark	Polen	U.S. Forest Service, Rhinelander, WI
LD-5-81	Nodebo, Denmark	Polen	U.S. Forest Service, Rhinelander, WI
LD-6-81	Palsgaard, Denmark	Polen	U.S. Forest Service, Rhinelander, WI
LD-7-81	SSUI[b]	SSUI	Hammermill Paper Co., Warren, PA
LD-8-81	SSUI[b]	SSUI	Hammermill Paper Co., Potter, PA
LD-9-81	SSUI[b]	SSUI	Hammermill Paper Co., Potter, PA
LD-10-81	SSUI[b]	SSUI	Hammermill Paper Co., Potter, PA
LD-11-81	SSUI[b]	SSUI	Hammermill Paper Co., Warren, PA
LD-12-81	SSUI[b]	SSUI	Scott Paper Co., Waterville, ME
LD-13-81	SSUI[b]	SSUI	Scott Paper Co., Waterville, ME

See end of table for footnotes.

APPENDIX

TABLE XIV (Continued)

EUROPEAN LARCH PARENT TREE SELECTIONS
SEED ORIGIN

Material	Origin	Distribution Group[a]	Cooperator and Location
LD-1-82	Zagnansk, Poland	Polen	U.S. Forest Service, Rhinelander, WI
LD-2-82	Lot 55, Sweden	SSUI	U.S. Forest Service, Rhinelander, WI
LD-3-82	Zagnansk, Poland	Polen	U.S. Forest Service, Rhinelander, WI
LD-4-82	Berthierville, Quebec	SSUI	U.S. Forest Service, Rhinelander, WI
LD-5-82	Berthierville, Quebec	SSUI	U.S. Forest Service, Rhinelander, WI
LD-6-82	Berthierville, Quebec	SSUI	U.S. Forest Service, Rhinelander, WI
LD-7-82	Berthierville, Quebec	SSUI	U.S. Forest Service, Rhinelander, WI
LD-8-82	Berthierville, Quebec	SSUI	U.S. Forest Service, Rhinelander, WI
LD-9-82	Berthierville, Quebec	SSUI	U.S. Forest Service, Rhinelander, WI
LD-10-82	Berthierville, Quebec	SSUI	U.S. Forest Service, Rhinelander, WI
LD-11-82	Dobris, Czechoslovakia	SSUI	U.S. Forest Service, Rhinelander, WI
LD-12-82	Dobris, Czechoslovakia	SSUI	U.S. Forest Service, Rhinelander, WI
LD-13-82	Zabreh-Dubicko, Czechoslovakia	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-14-82	Ruda nad Morovou, Czechoslovakia	Sudeten	U.S. Forest Service, Rhinelander, WI
LD-15-82	Skarzysko, Poland	Polen	U.S. Forest Service, Rhinelander, WI
LD-16-82	Skarzysko, Poland	Polen	U.S. Forest Service, Rhinelander, WI
LD-17-82	Schlitz, Germany	SSUI	U.S. Forest Service, Rhinelander, WI
LD-18-82	Skarzysko, Poland	Polen	U.S. Forest Service, Rhinelander, WI
LD-19-82	Schlitz, Germany	SSUI	U.S. Forest Service, Rhinelander, WI
LD-20-82	Unknown	Unknown	Diamond International, Milo, ME
LD-22-82	Pinczow, Poland	Polen	State of New Hampshire, Hillsboro, NH
LD-23-82	Salzburg, Austria	Alpen	State of New Hampshire, Hillsboro, NH
LD-24-82	Brenensky, Czechoslovakia	Sudeten	State of New Hampshire, Hillsboro, NH
LD-26-82	Salzburg, (Bluhnbach) Austria	Alpen	State of New Hampshire, Hillsboro, NH
LD-27-82	SSUI	SSUI	University of Maine, Orono, ME
LD-28-82	SSUI	SSUI	University of Maine, Orono, ME
LD-1-83	SSUI	SSUI	Champion International, Nathan, MI
LD-2-83	Val di Fiemme, Italy	Alpen	State of New Hampshire, Hillsboro, NH
LD-3-83	County Moray, Scotland	SSUI	State of New Hampshire, Hillsboro, NH

[a]Four separate distributional groups are recognized within the geographical range of European larch: Alpen, Sudeten, Tatra, and Polen plus several smaller outliers in Rumania. Major genetic differences are found between and within these groupings.
[b]Seed source under investigation.

APPENDIX

TABLE XV

JAPANESE LARCH PARENT TREE SELECTIONS
SEED ORIGIN

Material	Origin	Cooperator and Location
LL-4-59,S-1	Nagano Prefecture, Japan	IPC Larch Trial III, Clintonville, WI
LL-4-59,S-2	Nagano Prefecture, Japan	IPC Larch Trial III, Clintonville, WI
LL-12-59,S-1	Hokkaido, Japan	IPC Larch Trial III, Clintonville, WI
LL-1-80	Nagano Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-2-80	Nagano Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-3-80	Nagano Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-4-80	Nagano Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-5-80	Tochigi Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-6-80	Tochigi Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-7-80	Nagano Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-8-80	Nagano Prefecture, Japan	Iowa Conservation Commission, McGregor, IA
LL-9-80	Latitude 35° 54', longitude 137° 34'	Packaging Corporation of America, Bear Lake, MI
LL-10-80	Latitude 35° 54', longitude 137° 34'	Packaging Corporation of America, Bear Lake, MI
LL-11-80	SSUI[a]	Pennsylvania Bureau of Forestry, Harrisburg, PA
LL-12-80	SSUI[a]	Pennsylvania Bureau of Forestry, Harrisburg, PA
LL-13-80	SSUI[a]	Pennsylvania Bureau of Forestry, Harrisburg, PA
LL-14-80	SSUI[a]	Pennsylvania Bureau of Forestry, Harrisburg, PA
LL-15-80	SSUI[a]	Pennsylvania Bureau of Forestry, Harrisburg, PA
LL-16-80	SSUI[a]	Pennsylvania Bureau of Forestry, Harrisburg, PA
LL-17-80	SSUI[a]	U.S. Forest Service, Rhinelander, WI
LL-18-80	SSUI[a]	U.S. Forest Service, Rhinelander, WI
LL-19-80	SSUI[a]	U.S. Forest Service, Rhinelander, WI
LL-20-80	SSUI[a]	U.S. Forest Service, Rhinelander, WI
LL-21-80	SSUI[a]	U.S. Forest Service, Rhinelander, WI
LL-22-80	SSUI[a]	U.S. Forest Service, Rhinelander, WI
LL-23-80	SSUI[a]	Glatfelter Pulp Wood Co., Hershey, PA
LL-24-80	SSUI[a]	Glatfelter Pulp Wood Co., Hershey, PA
LL-1-81	SSUI[a]	U.S. Forest Service, Rhinelander, WI
LL-3-81	Nagano Prefecture, Japan	U.S. Forest Service, Rhinelander, WI
LL-4-81	Gumma Prefecture, Japan	U.S. Forest Service, Rhinelander, WI
LL-6-81	Nagano Prefecture, Japan	U.S. Forest Service, Rhinelander, WI
LL-7-81	Nagano Prefecture, Japan	U.S. Forest Service, Rhinelander, WI
LL-8-81	Nagano Prefecture, Japan	U.S. Forest Service, Rhinelander, WI
LL-9-81	Nagano Prefecture, Japan	U.S. Forest Service, Rhinelander, WI
LL-10-81	Nagano Prefecture, Japan	U.S. Forest Service, Rhinelander, WI
LL-11-81	Nagano Prefecture, Japan	U.S. Forest Service, Rhinelander, WI
LL-12-81	SSUI[a]	Scott Paper Co., Oxford City, ME
LL-2-59,S-1	Nagano Prefecture, Japan	IPC Larch Trial III, Clintonville, WI
LL-5-82	Hokkaido, Japan	IPC Larch Trial I, Eagle River, WI
LL-6-82	Hokkaido, Japan	IPC Larch Trial I, Eagle River, WI
LL-7-82	SSUI	International Paper Co., Readfield, ME
LL-8-82	SSUI	Glatfelter Pulp Wood Co., Fort Littleton, PA
LL-9-82	Yokohama, Japan	Glatfelter Pulp Wood Co., Huston, PA
LL-10-82	Yokohama, Japan	Glatfelter Pulp Wood Co., Maddensville, PA
LL-11-82	Yokohama, Japan	Glatfelter Pulp Wood Co., Huston, PA
LL-12-82	Yokohama, Japan	Glatfelter Pulp Wood Co., Huston, PA
LL-13-82	SSUI	Diamond International, Milo, ME
LL-1-83	Yatsuga Mts., Japan	University of Wisconsin, Rhinelander, WI
LL-2-83	Yatsuga Mts., Japan	University of Wisconsin, Rhinelander, WI
LL-3-83	Yatsuga Mts., Japan	University of Wisconsin, Rhinelander, WI
LL-4-83	SSUI	University of Wisconsin, Rhinelander, WI
LL-5-83	SSUI	University of Wisconsin, Rhinelander, WI
LL-6-83	Unknown	State of New Hampshire, Hillsboro, NH
LL-7-83	Central Japan	State of New Hampshire, Hillsboro, NH

[a]Seed source under investigation.

APPENDIX

TABLE XVI

LARIX GMELINI AND LARIX DAHURICA PARENT TREE SELECTIONS
SEED ORIGIN

Material	Origin	Cooperator and Location
LDa-1-83	Hokkaido, Japan	IPC Larch Trial III, Clintonville, WI
LDa-2-83	Hokkaido, Japan	IPC Larch Trial III, Clintonville, WI
LDa-3-83	Unknown	State of New Hampshire, Hillsboro, NH
LDa-4-83	Hokkaido, Japan	IPC Larch Trial III, Clintonville, WI

GLOSSARY

FOREST GENETICS TERMS

Clone - A group of plants derived from a single individual (ortet) by asexual reproduction. All members (ramets) of a clone have the same genotype and, consequently, tend to be uniform.

Compression wood - Wood of dense structure formed at the bases of some trees and on the underside of branches in conifers.

Cyclophysis - Abnormal growth that occurs in a graft when scion material is collected from too low an area in the crown.

Cytochromes - Cytochrome a, b, and c are heme-containing proteins widely occurring in cells and acting as oxygen carriers during cellular respiration.

F_1 generation - The first generation of a mating. If each parent is true breeding (homozygous), the F_1 individuals always resemble each other.

F_2 generation - The second generation successive to the parents and produced by crossing or selfing the F_1 individuals. The individuals within an F_2 generation characteristically vary greatly when their F_1 parent or parents are heterozygous.

F_3 generation - The third generation produced by intercrossing or selfing F_2 individuals. Individuals within an F_3 generation characteristically vary greatly.

Full-sib - Progeny, irrespective of sex, having the same male and female parent but from separate fertilizations.

Half-sib - Progeny, irrespective of sex, having only one parent in common.

Hedging - Reducing a plant to a more juvenile stage by repeatedly cutting it back and forcing a large number of shoots.

Heterozygosity - Presence in the same plant of both the dominant and recessive gene. A heterozygous individual characteristically does not breed true.

Homozygosity - Presence in a plant of either the dominant or recessive gene but not both. A homozygous individual breeds true when mated with the same genotype for the character(s) in question.

Inbreeding depression - Loss of vigor and/or fertility through intercrossing or selfing related organisms.

Isozyme (isoenzyme) - Multiple forms of a single enzyme. Isozymes often have different isoelectric points and therefore can be separated by electrophoresis.

Plagiotropism - A growth response to gravity, so that the axis of the plant member makes an angle other than 90° with the line of the gravitational field. See cyclophysis and topophysis.

Propagule - A plant part, such as a bud, tuber, root, or shoot, used to reproduce an individual asexually.

Provenance - The original geographic source of seed or propagules.

Topophysis - Abnormal growth that occurs in a graft when scion material is collected from the wrong branch positions.

PULPING AND SOLID WOOD PRODUCT TERMS

Basic density - Specific gravity of wood based on green volume. The term basic is applied since both green volume and ovendry weight are as nearly constant and reproducible measurements as can be obtained with wood.

Breaking length - The length of a strip, usually expressed in meters, which would break of its own weight when suspended vertically.

Bursting strength - The hydrostatic pressure in pounds per square inch required to produce rupture of the material when pressure is applied at a controlled increasing rate through a rubber diaphragm to a circular area.

CEDED bleaching - Sequence of chlorination, alkali extraction, chlorine dioxide, extraction, and chlorine dioxide.

Coarseness - The weight per unit length of a single fiber. Usually expressed as mg/100 m and considered to be useful in predicting fiber behavior in papermaking.

Density - Mass per unit volume; i.e., grams per cubic centimeter; lbs per cubic foot. See specific gravity.

Freeness - A measure of the rate at which water drains from a stock suspension through a wire mesh screen or a perforated plate. It is also known as "slowness" or "wetness" according to the type of instrument used in its measurement and the method of reporting results.

Furnish - The mixture of various materials that are blended in the stock suspension from which paper or board is made. The chief constituents are the fibrous material (pulp), sizing materials, wet-strength or other additives, fillers, and dyes.

Handsheet - A sheet made from a suspension of fibers in water, with or without the addition of sizing, loading, or coloring agents. Each sheet is formed separately by draining a pulp suspension on a stationary mold called a sheet mold. It is generally used for testing the physical properties of the pulp and/or the combinations of pulp with other material, in which case the sheet must be formed in accordance with standard procedures.

Kappa no. - Related to the amount of lignin left in the pulp. Decreasing numbers mean less lignin left in the pulp.

Modulus of elasticity - The proportionality constant (K) relating stress and deformation; it indicates the ability of the material to recover its original shape and size after the stress is removed.

Modulus of rupture - The maximum bending load to failure in pounds per square inch.

Specific gravity - The ratio of weight of a substance to the weight of an equal volume of water. Usually expressed as moisture free weight over green volume.

Spiral grain - Grain in which the fibers are aligned in a helical orientation around the axis of the stem.

Tearing resistance - The force required to tear a specimen under standardized conditions. There are three terms in common usage: (1) internal (or continuing) tearing resistance, wherein the edge of the specimen is cut prior to the actual tear. The value is commonly expressed in grams of force required to tear a single sheet. (2) "Edge tearing resistance." (3) Torsion tearing resistance of paper or paperboard is the energy expended in propagating a tear when the tearing force is applied in such a manner as to create a twist or torque.

Tensile strength - The force, parallel with the plane of the paper, required to produce failure in a specimen of specified width and length under specified conditions of loading. This definition must be distinguished from that which is commonly used in engineering practice and which expresses the tensile strength in force per unit area. In the paper industry, it is expressed as load per unit width or as "breaking length."

Zero-span tensile strength - The tensile strength of a sheet of fibrous material, measured with special jaws, at an apparent initial span of zero. It is an indication of the strength of the material comprising the fiber.